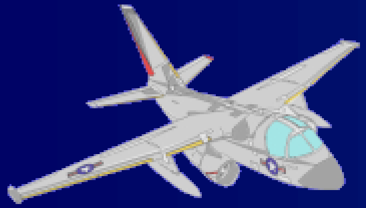

S-3B Flight Data Computer Replacement: A Legacy Systems Challenge

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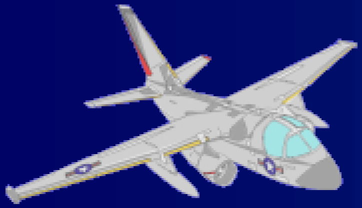
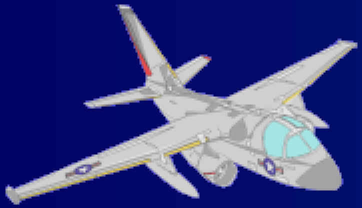


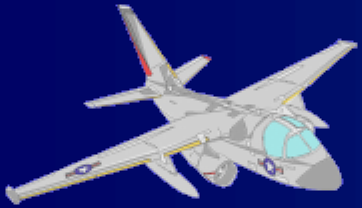
Abstract

The S-3B anti-submarine/surface-warfare airplane has been in service since the early 1970s. Over time, the materiel condition of the integrated autopilot system consistently degraded. By the late 1990s the autopilot mean-time-between-failure was dropping toward 30 hours, with significant impact on mission readiness. A new digital autopilot computer was planned to replace the central component, yet without replacing any of the controls, sensors, actuators, or wiring. During the upgrade design and integration, numerous challenges were met successfully, ranging from lack of original documentation to high-failure-rate external components. The upgraded autopilot is currently being fielded in the S-3B fleet, resulting in improved readiness, better airplane troubleshooting and maintenance, and restoration of lost autopilot functionality. The S-3B autopilot upgrade strategy, process and methods may apply to future upgrades for other legacy systems.

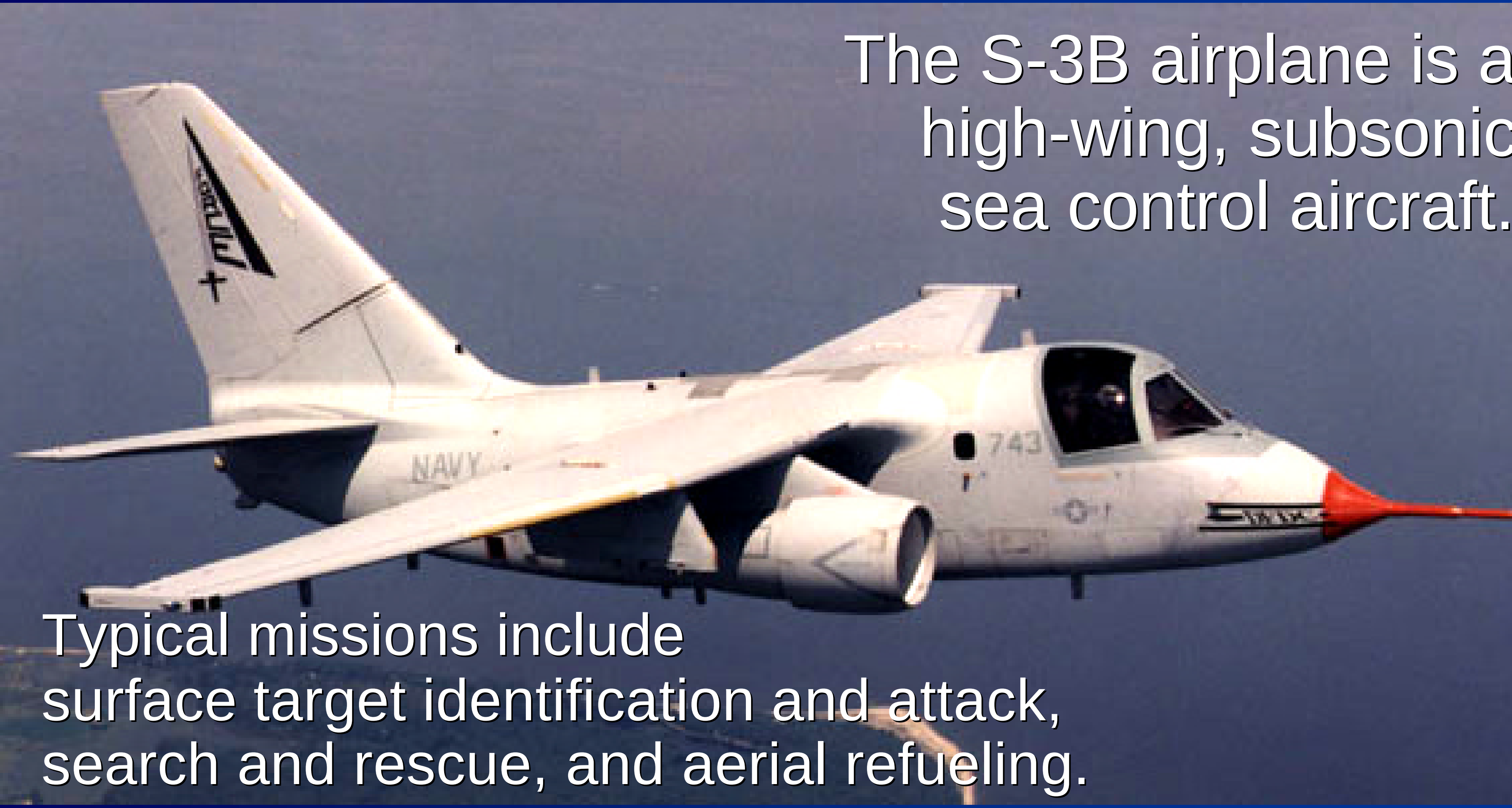


Introduction

- Focus on:
  - US Navy S-3B Airplane
  - Digital Flight Data Computer (DFDC) test program
- Relevance:
  - Any legacy system upgrade/replacement
  - Lessons may also apply to non-flying equipment

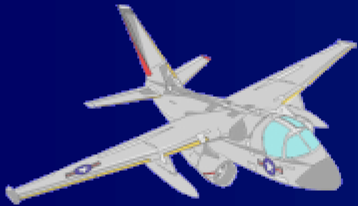


S-3B Airplane



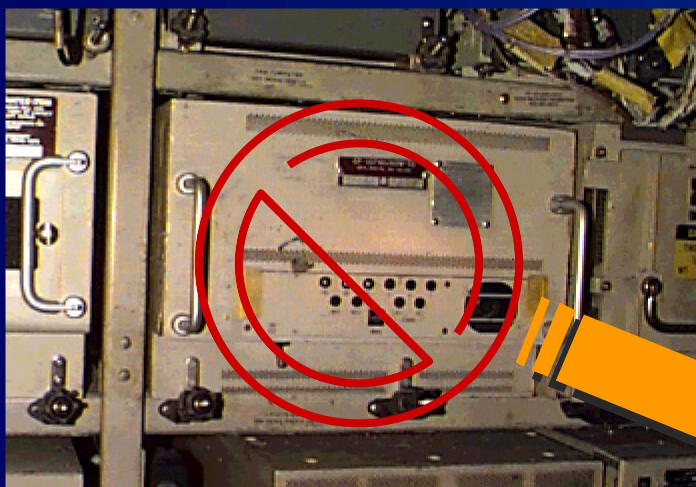
The S-3B airplane is a high-wing, subsonic sea control aircraft.

Typical missions include surface target identification and attack, search and rescue, and aerial refueling.



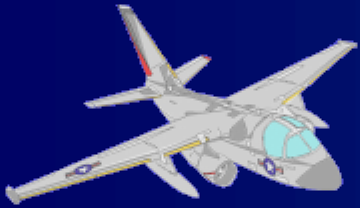
Unit Under Test

The DFDC was designed to replace an aging and unreliable Flight Data Computer (FDC)

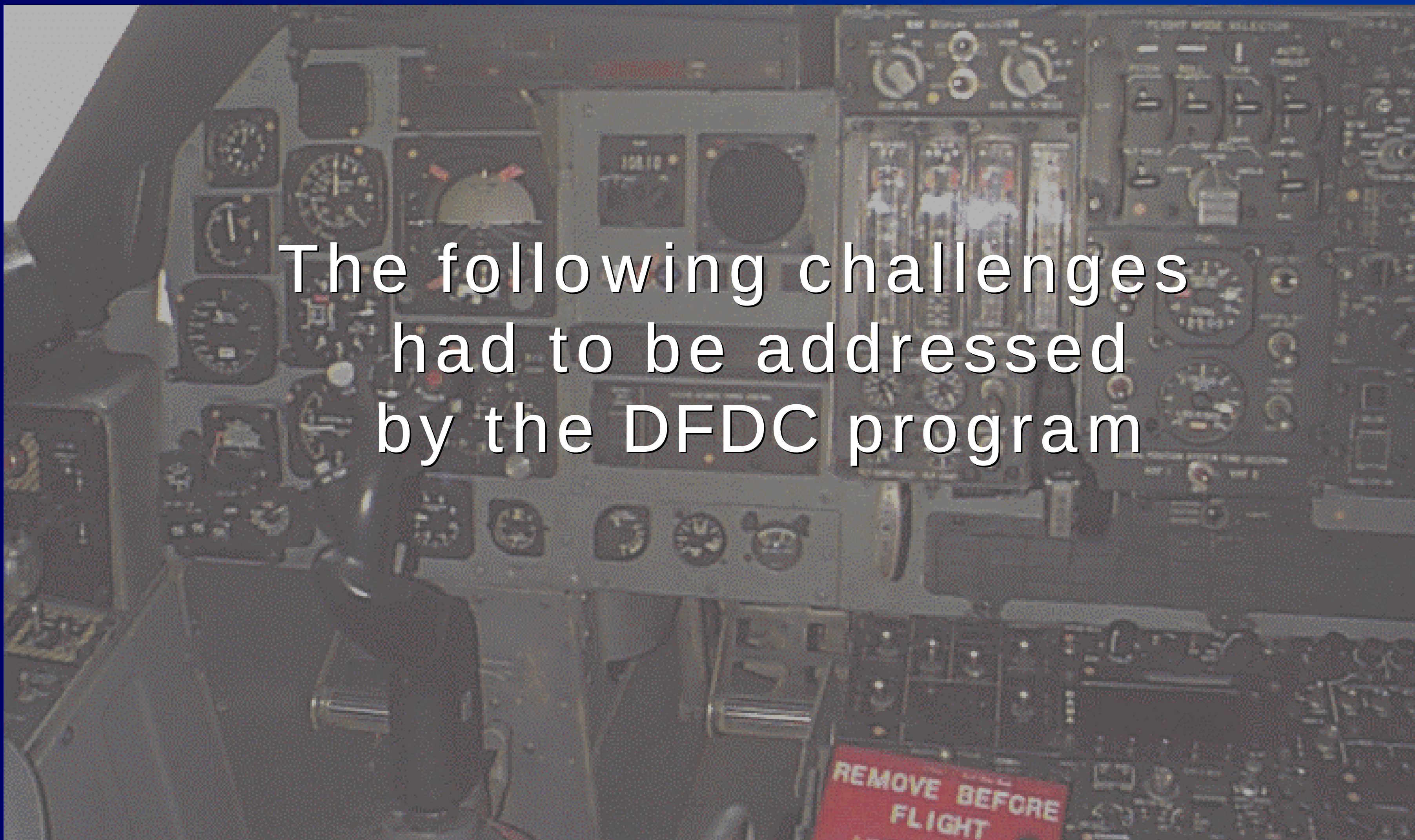


30 hour MTBF

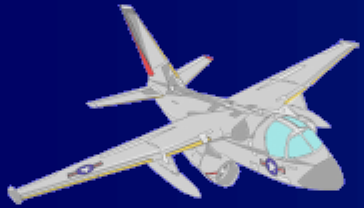
Projected 2,000 hour MTFB



Challenges

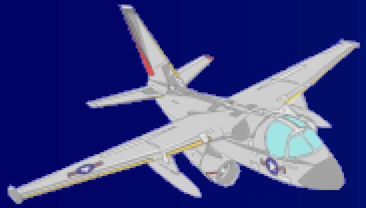


The following challenges had to be addressed by the DFDC program



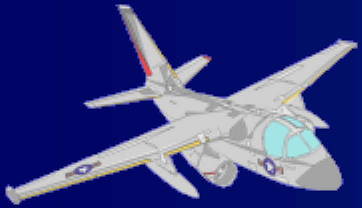
Integration Challenges

- Lack of background knowledge
  - For control laws
  - For electrical interfaces
  - For related actuators and sensors
  - For redundancy management design
- Poor legacy system documentation
  - Airframe plant closed
  - Documents lost or destroyed
  - Unrecoverable information
  - Personnel retired



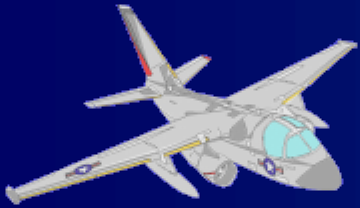
Integration Challenges

- Un-maintained disconnected systems
  - Roll axis disabled in 1991
  - No maintenance from 1991 to 2000
- Minimal maintenance of failure-prone systems
  - Fleet budget issues
  - Non-essentials not well maintained
  - All subsystems failure-prone
  - Overall system degraded over time



Integration Challenges

- Inadequate Fault Isolation
  - Minimal troubleshooting information for maintainers
  - 10 total indications for about 600 wires and 30 subsystems
- Difficulty Procuring "Golden" Legacy Equipment For Development Testing
  - Needed known good unit
  - Required for background research
  - Required for comparative testing



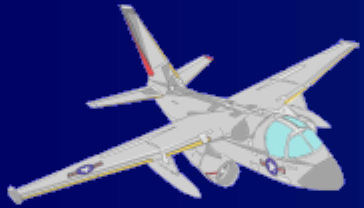
Integration Challenges

- Old Airplane Systems Interfacing With New Equipment
  - Only central computer replaced
  - Dual-channel miscompares
  - High failure rate of legacy subsystems

- Redundancy Concerns
  - Redundancy abandoned long ago by fleet
  - Contractor liability concerns for new unit
  - Better cockpit fault indications desired
  - No cockpit modifications allowed

Solutions

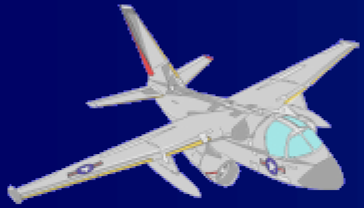
The following solutions were created for and applied to the DFDC program



Integration Solutions: Research

- Research on Legacy System
  - Data search
  - Document reconstruction
  - Interviews

- Evaluation of Legacy Sensors and Actuators
  - Key components provided to contractor
  - Detailed operational testing



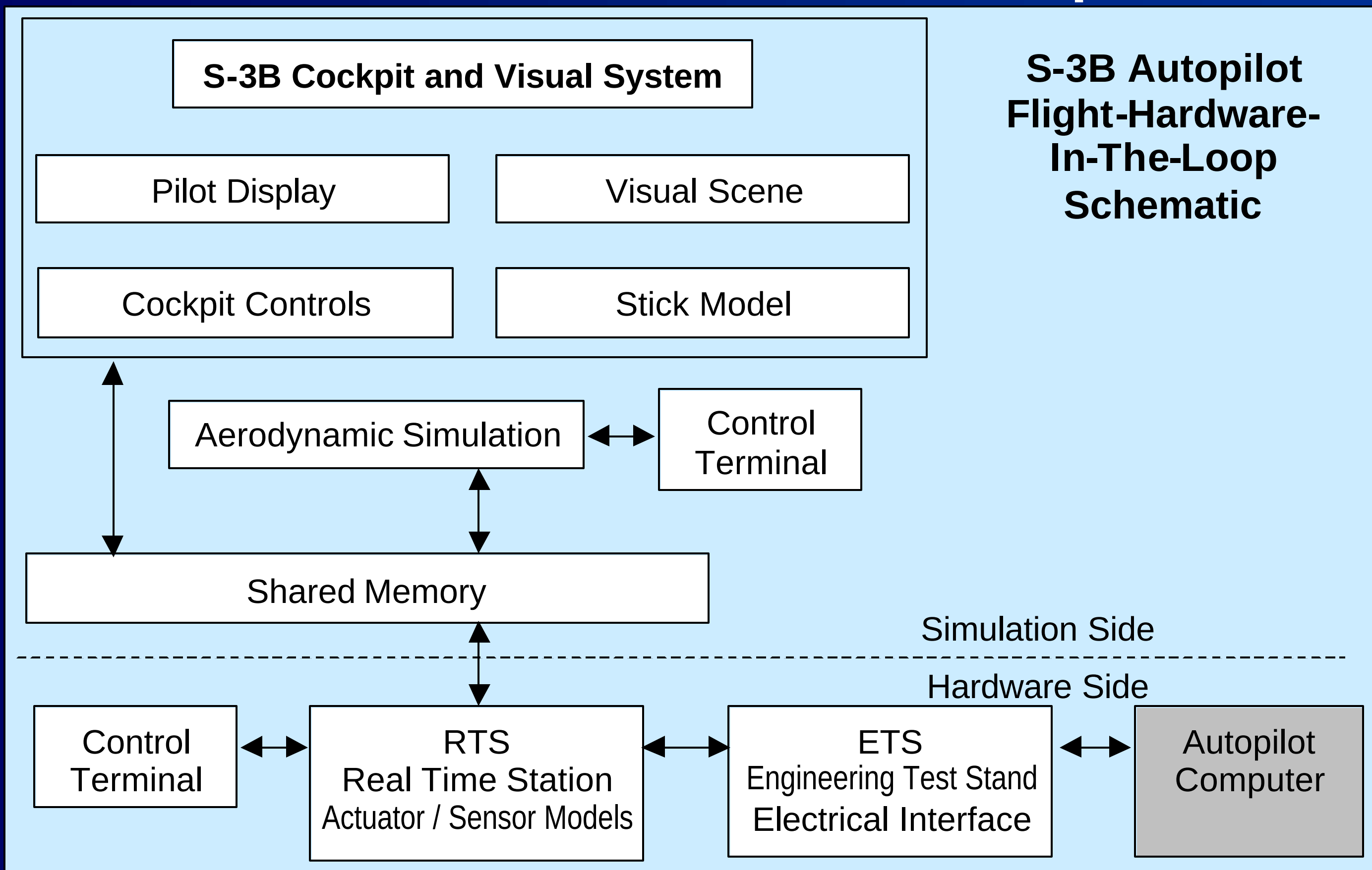
Integration Solutions: Testing

- "Maintenance Trainer" Testing
  - Designed to train maintainers
  - Used to research legacy system
  - Validated replacement system

- Software Simulation
  - High-fidelity airframe simulation
  - FORTRAN model of legacy autopilot
  - FORTRAN model of replacement autopilot
  - "Real" control law simulations

Integration Solutions: Hardware Testing

- Hardware-in-the-Loop Simulation



- Cockpit/ visual systems
- Airframe simulation
- Shared memory
- Hardware interface
- Autopilot computer

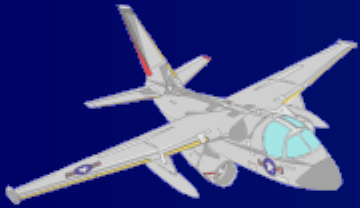
NAWCAD Patuxent River, MD- Manned Flight Simulator Test Setup

Integration Solutions: Simulation Lab

- Pilot-in-the-Loop Simulation

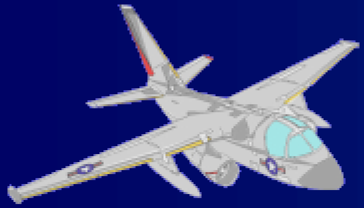
- Manned cockpit
- Operator station
- Interfaced with Autopilot Computer

NAWCAD Patuxent River, MD- Manned Flight Simulator Lab Station



Integration Solutions: Comparative Tests

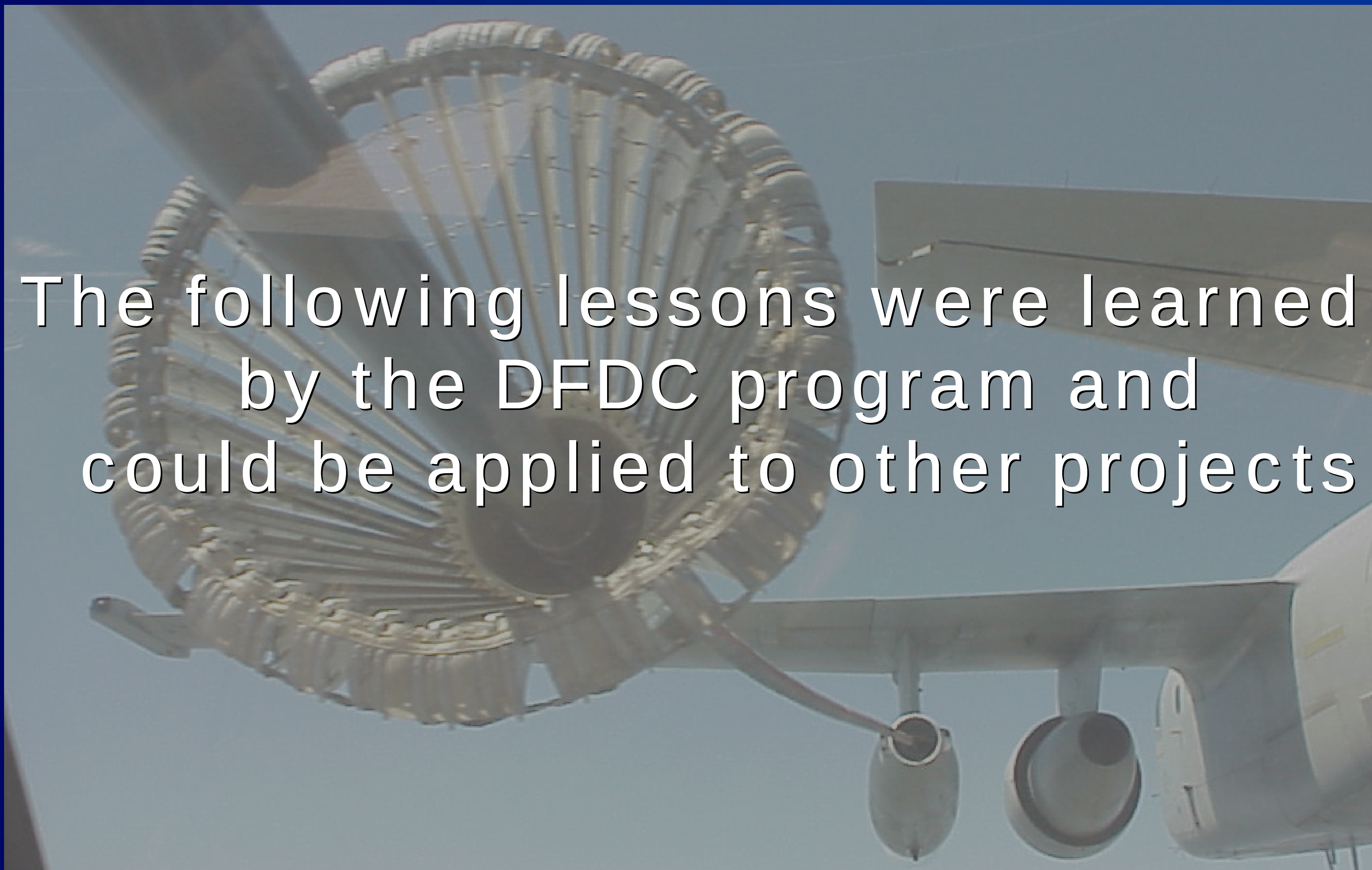
- Legacy and Replacement Side-by-Side Evaluation
  - Both legacy and replacement autopilots tested
  - Automated tests allowed thorough evaluation of replacement autopilot
  - Automated tests previewed against legacy autopilot
  - Data comparison highlighted changes



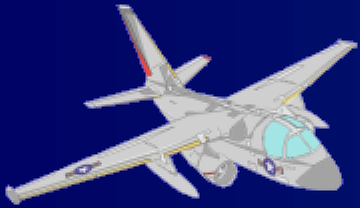
Integration Solutions: Block Diagrams

- Detailed system block diagrams constructed
  - Both legacy and replacement autopilots diagrammed
  - Included in design specifications
  - Required as contractor deliverables
  - Essential for later troubleshooting

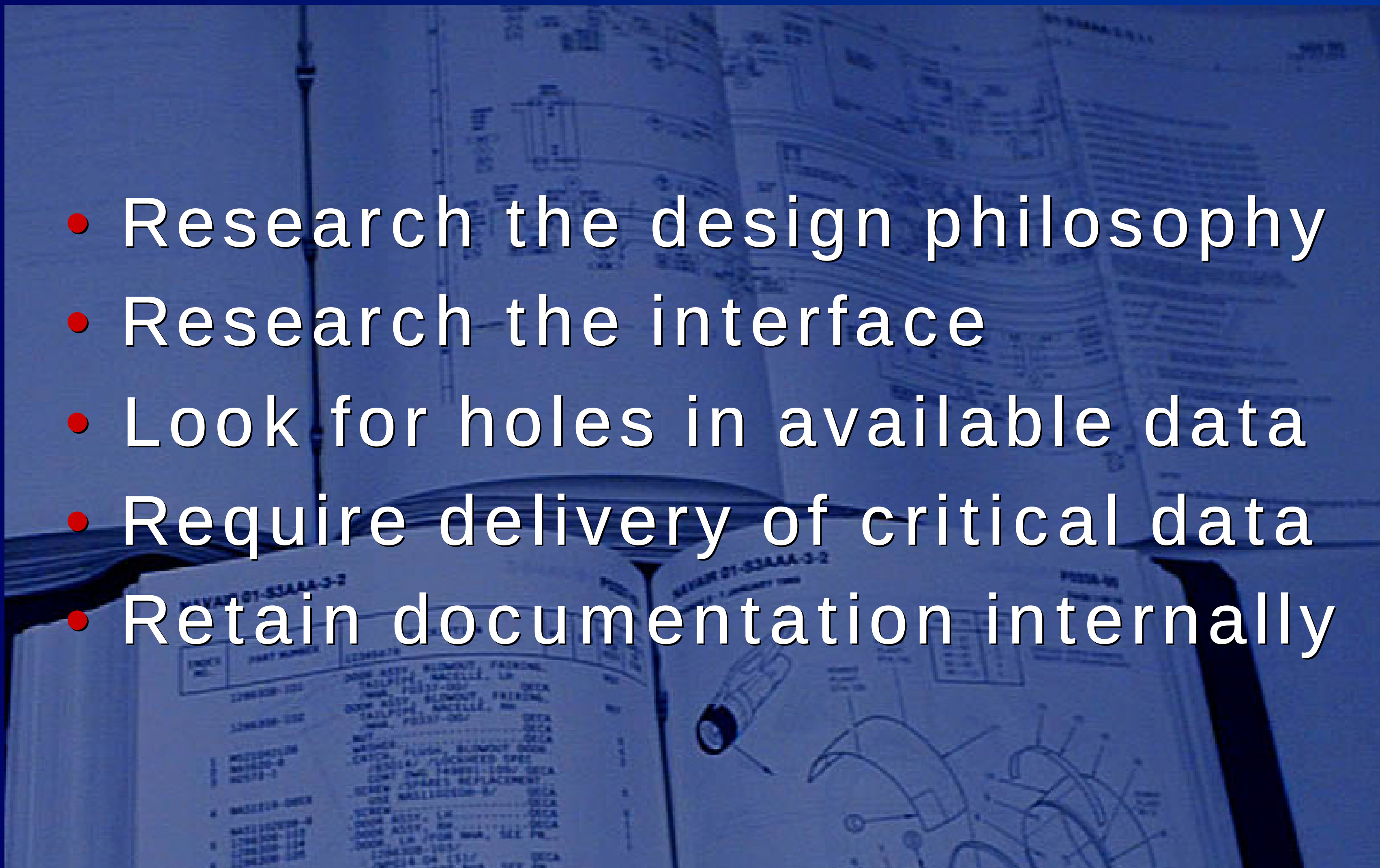
Lessons Learned



The following lessons were learned by the DFDC program and could be applied to other projects

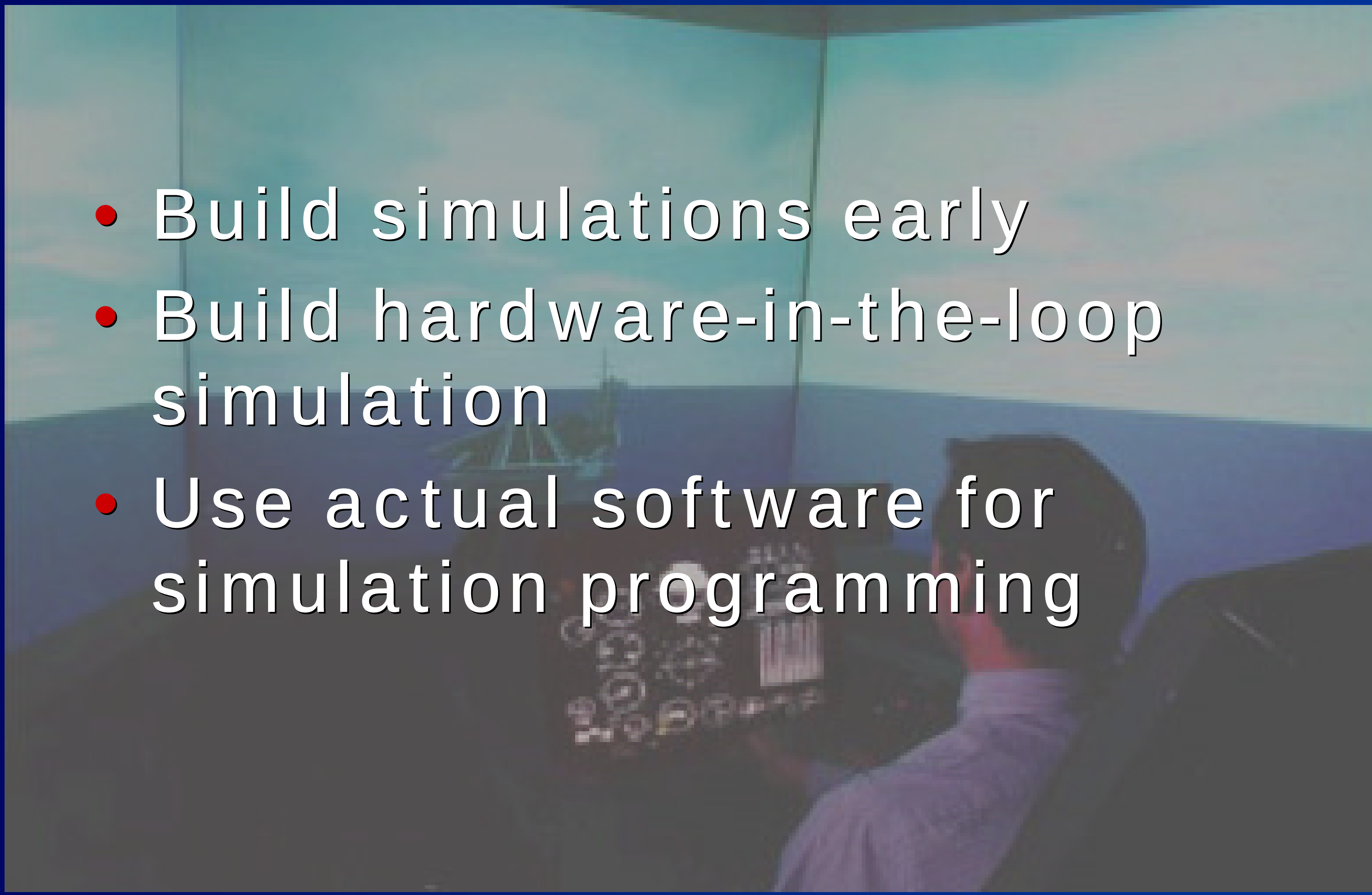


Integration Lessons: Background Research

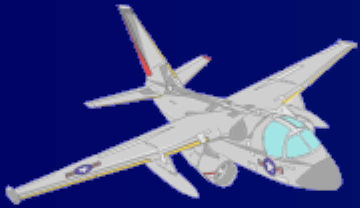


- Research the design philosophy
- Research the interface
- Look for holes in available data
- Require delivery of critical data
- Retain documentation internally

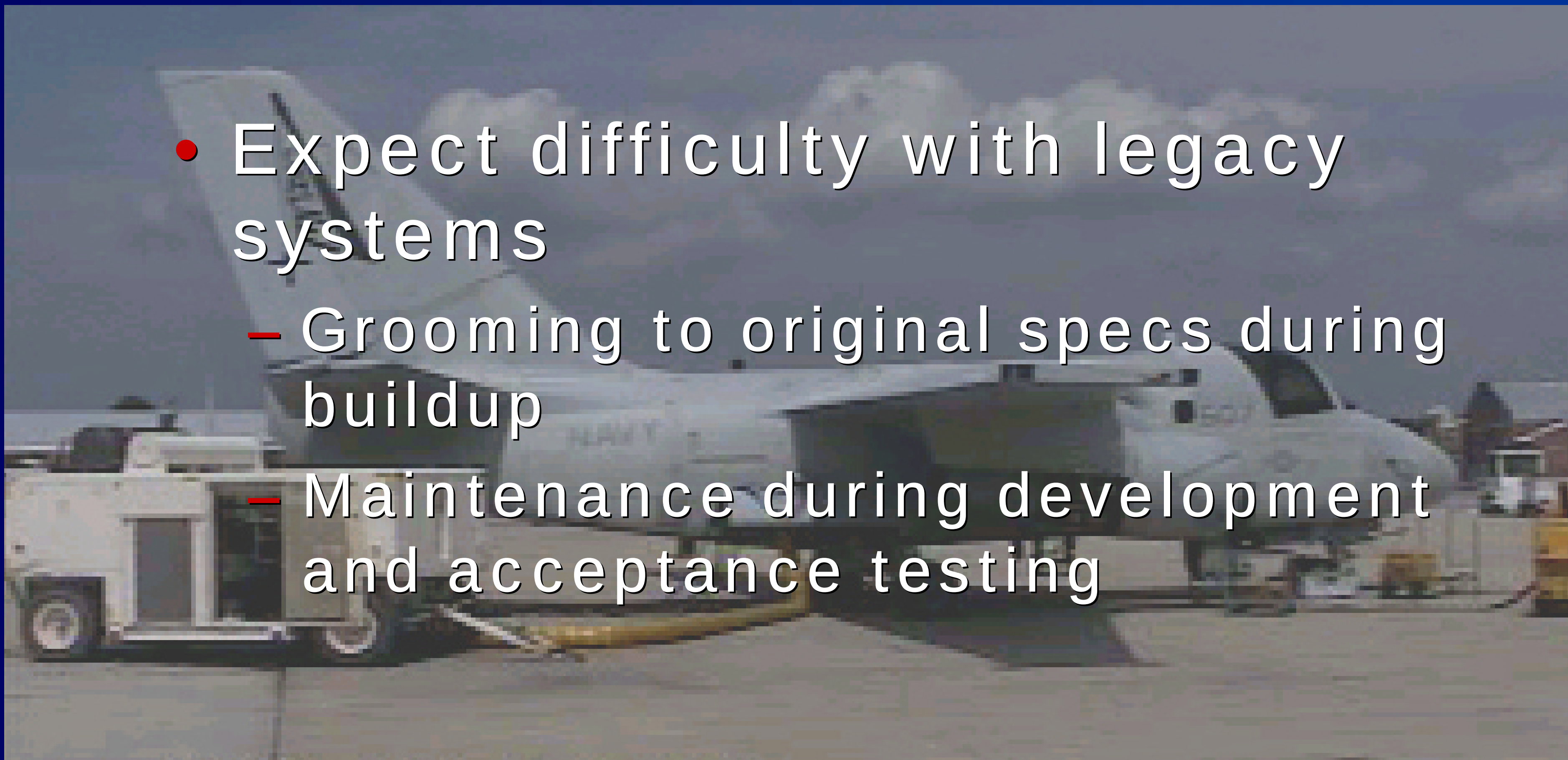
Integration Lessons: Simulation



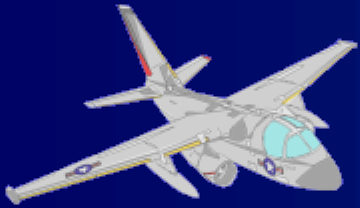
- Build simulations early
- Build hardware-in-the-loop simulation
- Use actual software for simulation programming



Integration Lessons: Installation

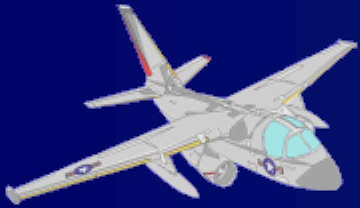


- Expect difficulty with legacy systems
  - Grooming to original specs during buildup
  - Maintenance during development and acceptance testing



Integration Lessons: Maintenance

- Maintenance personnel can be resistant to change
  - "That's the way we've always done it"
- Expect maintenance practice inertia
  - Pubs changes take time
  - Modified tools and test kits

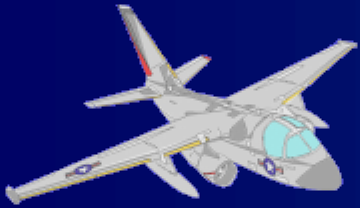


Integration Lessons: Restoring Lost Functions

- Anticipate trouble introducing new or restored functions
  - Introducing and training new functions takes time
  - Changing the “old way” of using the system
  - Unexpected compensation techniques for legacy problems

Integration Lessons: Multiple Upgrades

- Coordinate Multiple Upgrades
  - Coordinate requirements and designs
  - Earlier coordination is better
  - Use a standardized interface



Integration Lessons: Documentation

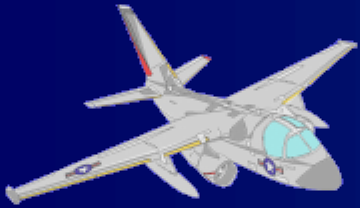
- Emphasize Final Documentation
  - Document deficiencies in view of future correction
  - Preserve corporate knowledge
  - Resist pressure to trim deliverables
  - Much cheaper to deliver now than (re)create later

Integration Lessons: Plan Ahead

- Funding pressures lead to upgrades (instead of replacements)
- Look beyond system being upgraded
- Provide for integration even if not currently required
- Assume new system will one day be a legacy system
- Plan and budget for follow-on upgrades
  - Assume some problems will be found
  - Defend funding for follow-on work

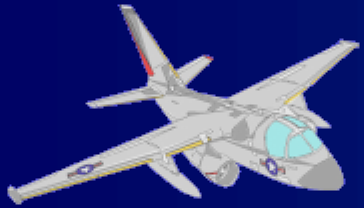
Conclusions

Proper planning for legacy system upgrades, and designing replacement systems with future upgrades in mind, can provide needed system improvements while maximizing the return on dollars spent



Q&A

Questions?



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